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SITE VISIT TO CERAMIC TILE MANUFACTURER A

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EASTERN RESEARCH GROUP

ARLINGTON, VA

SITE VISIT REPORT -
CERAMIC TILE MANUFACTURING FACILITY A

I. INTRODUCTION

Eastern Research Group, Inc. (ERG) conducted an industrial hygiene site visit in January 2001 to a ceramic tile manufacturing facility (hereafter referred to as Ceramic Tile Manufacturing Facility A), located in the central time zone of the United States. The purpose of the site visit was to obtain information regarding the use of materials containing crystalline silica (hereafter referred to as "silica") in the manufacture of ceramic tiles; gather information on the respirable silica exposures of workers at the facility; and document the controls in place to reduce exposure. In particular, the site visit was intended to evaluate the exposures of workers who perform milling, forming, glazing, and bag emptying operations.

On January 8, 2001, three ERG industrial hygienists met with representatives of Ceramic Tile Manufacturing Facility A to discuss the clay tile manufacturing process, the materials used in the process, and the job categories with potential for silica exposure. A walk-through of the facility was conducted as part of the meeting. On January, 9, 2001, ERG conducted full-shift personal breathing-zone (PBZ) air monitoring and observed the work practices of employees identified as having potential for exposure to silica. Bulk samples were obtained to determine the silica concentrations of various work materials and settled dust. ERG also conducted an evaluation of local exhaust ventilation (LEV) systems in place at several workstations.

Ceramic Tile Manufacturing Facility A is a large facility (by industry standards) employing a few hundred workers, with approximately two-thirds involved in production activities. According to the 1997 Economic Census, 154 (91 percent) of the 169 ceramic wall and floor tile manufacturing facilities in the United States employed fewer than 250 workers; 119 (70 percent) of the facilities employed fewer than 20 workers (U.S. Department of Commerce, 1999). The Tile Council of America considers the production methods used at Ceramic Tile Manufacturing Facility A to be fairly typical of the industry (TCA, 2000).

The facility is a 300,000 ft^2 building including covered raw material storage areas where raw materials are stored and processed; a body preparation room where the clay mixture is milled and spray dried; a main production area where tiles are formed, glazed, fired, and packaged; break rooms; a laboratory room where samples of raw materials, glazes, and tiles are tested; and rooms where glaze components are stored and batched. Ceramic Tile Manufacturing Facility A typically produces 140,000 ft^2 of tiles each day. The facility produced 114,744 ft^2 of tiles on the day during which air monitoring was conducted. The majority of the plant operates for two 10-hour shifts per day, four days per week. The kilns run continuously and operators work 12-hour shifts.

II. PROCESS DESCRIPTION

Ceramic Tile Manufacturing Facility A manufactures tiles from clays and silica sand. The facility also prepares and applies various silica-containing glazes to the tiles. The majority of the production process involves the use of automated machinery, which crush and grind raw materials, mill batches of clay, spray dry the clay, press the clay into tiles, brush and dry the tiles, apply glazes to the tiles, fire the tiles, and package tiles. Manual operations are used to charge ball mills, batch glazes, remove defective tiles from conveyors, and package certain tiles. Workers in the following job categories are potentially exposed to silica: clay handler, ball mill operator, spray dryer operator, press operator, glaze preparer, glazer, silk screen operator, kiln operator, seletor, forklift operator, mechanic, laboratory technician, and utility worker.

A clay handler oversees the storage and transport of raw materials (clays, sand, and fired tile scrap) to a covered storage area at one end of the facility. The facility receives raw clays (typically 15 percent silica and 10 percent moisture) and 30 mesh silica sand by dump truck. Fired tile scrap (recycled as a raw material), clays, and sand are stored in open piles inside the storage area, which has two openings to the outside of the facility. A clay handler uses a front-end loader to transfer clay into a "shredder," an automated machine that mills the clay to into course particles. A series of three crushers, also operated by the clay handler, processes tile scrap for recycling. Milled clay, sand, and crushed tile scrap are automatically transported through a series of open and covered conveyers into storage hoppers, and from there into the adjacent body preparation room.

A ball mill operator controls equipment that meters the correct proportions from the hoppers to ball mills through chute sleeves that are manually positioned. Water is simultaneously added into the balls mills through the chute sleeves, partially wetting the dry ingredients. The clay is milled to form a fine slurry (slip) with approximately 80 percent of the particles between 1.9 and 22 micrometers and approximately 30 percent of the particles smaller than 4 micrometers in size (respirable range). The ball mill operator uses pumps to transfer the slip into underground tanks, and then the operator oversees transfer of the slip from tank to tank through vibrating screens that remove oversized particles.

A spray dryer operator oversees transfer of the screened slip to an automated spray dryer that is also located in the body preparation room. The spray dryer sprays the slip upwards inside a heated chamber, and the clay dries as it falls back down. Water vapor removed from the clay exits the facility through a stack. The dried clay is a fine, granular material containing 6 percent to 7 percent moisture. The clay is transferred through a screen and onto a conveyor, tended by the spray dryer operator, that transports it to storage silos in the press area, which is located in the main production area of the facility.

Press operators oversee transfer of clay from the storage silos through screens and into four automated presses that compress the clay in molds to form tiles. The screens remove oversized clay particles, which are transferred into bins next to each press. The press operators monitor the presses and oversee conveyors that transport the pressed tiles through dryers that dry the tiles to 0.5 percent moisture. The dried tiles, "green tiles," are then conveyed to a glaze line adjacent to the press area in the main production area.

A glazes preparer, working in a glaze preparation room located adjacent to the main production area, batches glazes by manually emptying 50-pound bags of dry glaze components into hoppers. The glaze preparer uses an overhead crane to empty the hoppers into ball mills that mix the dry components with water. The liquid glaze mixtures are pumped into adjacent storage tanks. A glazer fills smaller tanks from the storage tanks and transports them with forklifts to the glaze line. At the glaze line, glazes are pumped from the tanks into conveyor-mounted applicator machines. The glazer monitors the automated machines as they apply liquid glaze to green tiles that are conveyed through them. The tiles are then conveyed to automated silk screen machines, monitored by a silk screen operator, that apply glaze paste patterns to the tiles.

A kiln operator loads glazed green tiles onto automated racks that transfer the tiles to kilns located in the main production area. Roller conveyors carry the tiles through the kilns, which fire the tiles at 2,200 degrees-Fahrenheit. The fired tiles are conveyed to selectors in the selection area of the facility. The selectors inspect the tiles and manually remove and discard defective tiles. Acceptable finished tiles are packaged manually by a selector or by automated machinery. The packaged tiles are palletized and transported to storage areas by a forklift operator.

A press mechanic, laboratory technician, and utility worker perform mobile duties where ever required to maintain equipment, provide quality control evaluations, and clean floors.

Several processes appeared to be sources of respirable silica exposure based on observations of visible airborne dust and the PBZ sample results. These processes (raw material handling operations, ball milling, spray drying, press operations, scrap green tile dumping, dry sweeping, and bag dumping) generated visible dust originating from silica-containing materials. In most cases (those involving milled clay) facility documents indicate that 30 percent of the particles are less than 4 micrometers in size (within respirable range). Thus, at this facility, ERG has noted the presence of visible dust as a potential marker for the presence of respirable crystalline silica, a practice that is not necessarily valid at other facilities. At Ceramic Tile Manufacturing Facility A, respirable silica exposure results for operators associated with the processes noted to generate the most visible dust were also among the highest results obtained during the site visit, as shown in the following section.

Potential sources of respirable quartz exposure for each job category are summarized in Table 1 and presented in detail, along with descriptions of specific worker activities, in Appendix A.

Air velocity measurements were made using an Alnor ThermoAnemometer, model 8565 (serial number 2519), factory calibrated January, 2000 (calibration due January 24, 2001). ERG used an MSA Ventilation Smoke Tube Kit to evaluate flow direction.

B. Air Monitoring Results

Table 2 presents the time-weighted average (TWA) results of the 16 full-shift PBZ samples (sample durations ranging from 367 minutes to 495 minutes) and the 333-minute PBZ sample collected on January 9, 2001. As Table 2 indicates, quartz was detected at quantifiable levels in 13 of the 17 PBZ samples. The results indicate measurable respirable quartz exposure levels ranging from 57 $\mu g/m^3$ (laboratory technician) to 337 $\mu g/m^3$ (spray dryer operator). Quartz was not detected in the samples for the kiln operator or either selector (trim line and selection area). Cristobalite was not detected in any of the PBZ samples. The limit of detection (LOD) for quartz in air samples is 10 micrograms (μg) per sample (approximately 12 $\mu g/m^3$ for a full-shift, 480-minute, 816-liter sample), and the LOD for cristobalite in air samples is 30 μg per sample (approximately 37 $\mu g/m^3$ for a full-shift, 480-minute, 816-liter sample). The analysis resulted in an LOD of less than or equal to 18 $\mu g/m^3$ for one forklift operator (selection area). The 17 TWA PBZ results indicate respirable dust exposure levels ranging from 176 $\mu g/m^3$ (forklift operator for the selection area) to 2,594 $\mu g/m^3$ (spray dryer operator). Ten of the 17 results indicate exposure levels exceeding OSHA's 8-hour TWA permissible exposure limit (PEL) for quartz (measured as respirable dust containing quartz). No respirable dust results exceeding the OSHA 8-hour TWA permissible exposure limit (PEL) of 5 mg/m^3 for respirable dust not containing crystalline silica.

The conditions and activities associated with these sample results represent a typical work shift at Ceramic Tile Manufacturing Facility A. Reportedly, the facility floors are cleaned with a power sweeper two to three times per day for four days of the week, and the floor at the press area and glaze line is mopped two times per week. The day air monitoring was conducted was one of the days during which floors are both power-swept and mopped. Workers cleaned the floor of the main production area with a power sweeper twice and a worker used a wet mop to clean the floor at the press area and glaze line throughout the day. Noticeably less airborne and settled dust was observed during the day when air monitoring was conducted than during the previous day when the walk-through was conducted.

The results indicate that several processes performed at the facility during the site visit generated detectable levels of respirable silica. A gradient in exposure readings for certain workers in the main production room also suggests that exposure levels for some workers were affected more by ambient respirable silica than their work activities. To illustrate this point, results for job categories are discussed in the order of their physical work position within the building, rather than strictly in the order of the process flow described in the process description.

Clay Handler: A respirable silica exposure reading of 157 $\mu g/m^3$ was obtained for the clay handler. ERG observed multiple potential sources of respirable silica exposure in the raw materials storage area. Dust was generated as dump trucks unloaded raw materials and when the clay handler charged hoppers with clay and sand. Dust was also released from conveyors carrying crushed raw materials. The clay shredder and crusher (not observed) are other potential exposure sources.

Ball Mill Operator and Spray Drier Operator: The two highest respirable silica exposure readings were obtained for the ball mill operator (226 $\mu g/m^3$) and the spray dryer operator (337 $\mu g/m^3$). The two operators worked at adjacent workstations in the body preparation room. Visible airborne dust was released when the ball mill operator manually brushed dried clay residue from mill hatches and used a pneumatic wrench to remove bolts from the hatches. Visible airborne dust was also released as spray-dried clay poured out of the spray dryer and onto a conveyor belt. The exposure levels may have been higher in the body preparation room than in the raw materials storage area because the exposure levels for the ball mill operator and spray dryer operator are primarily associated with milled clay, which contains a greater proportion of respirable particles (30 percent of the particles are smaller than 4 microns after milling). Additionally, contaminated air from the raw materials area can enter the body preparation room and contribute to the exposures of the ball mill operator and spray dryer operator. The exposure reading for the spray dryer operator may have been higher than the exposure reading for the ball mill operator because the spray dryer operator worked closer to the spray dryer, suspected as the primary source of visible airborne dust in the room, and manually handled clay dust at intervals throughout the shift.

Press Operators: A reading of 188 $\mu g/m^3$ was obtained for the Martinelli press operator. The Martinelli press did not release visible dust. However, the Martinelli press operator generated substantial dust by manually brushing pressed tiles and dry sweeping a work table for approximately half of the sampling period.

Exposure readings of 144 $\mu g/m^3$ and 141 $\mu g/m^3$ were obtained for the two press operators who worked at adjacent workstations on press lines three through six. ERG observed visible airborne dust generation by pressing operations in the press area. Visible airborne dust was released from the presses as automated air jets blew residual clay from the molds at the start of each pressing cycle. Dust was also generated as the press operators dry swept the floor and manually threw defective tiles into scrap bins.

Table 2. Full-Shift TWA Personal Breathing Zone Air Monitoring Results - Ceramic Tile Manufacturing Facility A January 9, 2001						
Sample Number	**Job Title**	**Sample Duration (minutes)**	**Sample Volume (liters)**	**Respirable Dust ($\mu g/m^3$)**	**Respirable Quartz[1] ($\mu g/m^3$)**	**Respirable Cristobalite[2] ($\mu g/m^3$)**
R979	Clay Handler	469	797	1,569[6]	157	ND
R831, R993[3]	Ball Mill Operator	474	806	2,056[6]	226	ND
S061	Spray Dryer Operator	454	772	2,594[6]	337	ND
R972	Press Operator (Martinelli Press)	450	765	1,881[6]	188	ND
R916	Press Operator (Lines 3 and 4)	480	816	1,305[6]	144	ND
R919	Press Operator (Lines 5 and 6)	483	821	1,553[6]	141	ND
S059	Glaze Preparer	492	836	622	68	ND
R967	Glazer	495	842	1,706[6]	150	ND
R913	Silk Screen Operator	494	840	1,166	73	ND
R868	Kiln Operator	367	624	236	ND	ND
S069	Selector (Trim Line)	490	833	184	ND	ND
R895[4]	Selector (Selection Area)	333	566	330	ND	ND
R936	Forklift Operator (Glaze Line)	465	790	886[6]	89	ND
R989	Forklift Operator (Selection Area)	482	819	176	≤18[5]	ND
R982	Press Mechanic	488	830	797[6]	65	ND
R931	Laboratory Technician	434	738	474	57	ND
R886	Utility Worker	492	836	927[6]	82	ND

[1] ND = not detected. The LOD for quartz is 10 μg per sample.
[2] ND = not detected. The LOD for cristobalite is 30 μg per sample.
[3] Two sample filters were used and the TWA calculated.
[4] This sample was not collected over a full shift. The pump was removed early to accommodate the worker.
[5] Quartz was not positively identified in this sample. This value represents the maximum amount of quartz that could be present.
[6] Exceeds the OSHA 8-hour TWA permissible exposure limit (PEL) for respirable quartz (measured as respirable dust containing quartz).

The exposure levels for the press operators may also have been affected by contaminated air that can reportedly enter the press area from the body preparation room.

Glaze Preparer: An exposure result of 68 µg/m³ was obtained for the glaze preparer. Glaze preparation operations generated dust as the glaze preparer manually cut open bags of silica-containing materials and emptied them into open hoppers. Visible airborne dust was also generated as the glaze preparer dry swept the bag dumping station.

Forklift Operator (Glazing Line): A result of 89 µg/m³ was obtained for the glaze line forklift operator, who's activities generated additional dust in the press area. Dust was released as the glaze line forklift operator emptied bins of scrap green tile into an open, wall-mounted hopper and as the operator drove a power sweeper in the press area, re-suspending settled dust from the floor. Presumably, respirable silica released by pressing operations also contributed to the exposures of this worker.

Utility Worker: An exposure reading of 82 µg/m³ was obtained for the utility worker, who, like the forklift operator, drove the power sweeper. The utility worker also dry swept in the press area. Dust released by the presses may have contributed to the exposure of this worker, too.

ERG observed other workers (glazer, silk screen operator, trim line selector, selection area selector, kiln operator, and selection area forklift operator, press mechanic, and laboratory technician) in the main production area of the facility performing operations that did not appear to generate respirable silica. The **glazer** (with an exposure result of 150 µg/m³) worked adjacent to the press area and monitored automated machines that applied liquid glaze to green tiles and automatically brushed the tiles. The glaze sprayer machines and the brush machine were equipped with ventilated enclosures that appeared to effectively control dust. An exposure result of 73 µg/m³ was obtained for the **silk screen operator**, who monitored silk screen machines that applied paste glaze down the line from the glazer, and further from the press area. This worker handled wet glazes and cleaned and wiped screens and equipment using wet methods. The PBZ sample results for these workers suggest that their primary source of exposure was ambient respirable silica. A gradient in exposure levels for the workers indicates that the press area was the primary source of ambient respirable silica in the main production area. Exposure levels were higher for workers who worked closer to the press area.

Exposure readings are lower for workers who periodically entered the press area but spent the majority of the shift at other locations. A reading of 65 µg/m³ was obtained for the **press mechanic**, who occasionally entered the press area to monitor the presses, but otherwise worked in the maintenance shop. A reading of 57 µg/m³ was obtained for the **laboratory technician**, who periodically entered the press area and glaze line to collect samples, but spent the majority of the shift in the laboratory or in the selection area.

Exposure readings for workers who worked farthest from the press area are the lowest. Results below the limits of detection of less than or equal to 12, and in one case less than or equal to 18 $\mu g/m^3$, were obtained for the **kiln operator**, **selector (selection area)**, **selector (trim line)**, and **forklift operator (selection area).** Each of these workers spent the majority of the shift in or near the selection area, at the opposite end of the building from the body preparation and press areas, where they primarily handled hard fired tile. ERG noted little settled dust and observed no sources generating airborne dust in this area.

C. Bulk Sample Results

Table 3 summarizes the results of the six bulk samples collected during the shift. Three samples were collected from raw materials used to form the clay body of the tiles: Tulsa clay, raw orange clay, and Christy clay. One sample was collected from spray-dried clay in the body preparation room, and another sample was collected from fired, glazed tile in the selection area. In addition, a sample was collected from settled dust on the top of an ice maker inside the break room adjacent to the laboratory. As Table 3 indicates, quartz was detected in all of the bulk samples. The samples of Tulsa clay; raw orange clay; spray-dried clay; fired, glazed tile; and settled dust from the break room contained 20 percent quartz. The sample of Christy clay contained 5 percent quartz. Cristobalite was not detected in any of the samples. The LOD for cristobalite in bulk samples is 2 percent content. The results indicate that workers can potentially be exposed to respirable silica throughout the production process because quartz is present in the raw materials, processed clay, and final product.

The results also indicate that settled dust in the break room contains 20 percent quartz. Apparent sources include airborne dust from the adjacent body preparation room (the main door to which is near the break room door) and the nearby press area, as well as dust tracked in on workers' shoes. Air from production areas enters the break room each time the door opened.

Table 3. Bulk Sample Results - Ceramic Tile Manufacturing Facility A January 9, 2001			
Sample Number	**Sample Description**	**Quartz (%)**	**Cristobalite[1] (%)**
A1	Spray-dried clay. Collected from the body preparation room.	20	ND
B1	Fired, glazed tile. Collected from the selection area.	20	ND
C1	Tulsa clay. Collected from the raw materials storage area.	20	ND
D1	Raw orange clay. Collected from the raw materials storage area.	20	ND
E1	Christy clay. Collected from the raw materials storage area.	5	ND
F1	Settled dust collected from the top of the ice maker in the break room.	20	ND
[1] ND = not detected. The LOD for cristobalite is 2 percent sample content.			

IV. EXPOSURE CONTROLS IN PLACE

Ceramic Tile Manufacturing Facility A uses various methods to reduce worker exposure to airborne particles generated by raw material crushing and grinding, clay milling, spray drying, pressing, glaze application, glaze preparation, and green tile scrap dumping. LEV systems are used to reduce worker exposures associated with raw material crushing and grinding, ball mill charging, tile pressing, tile brushing, glaze application, glaze preparation, green tile scrap dumping, and clay reclamation from silos in the press area. Manual contact with silica-containing raw materials or product is reduced with the use of automated machinery such as the shredder, tile scrap crushers, ball mills, spray dryer, presses, conveyor-mounted dryers and brushes, glaze applicator machines, and silk screening machines. Worker enclosures, such as enclosed cabs for front-end loaders and control rooms for the clay handler and spray dryer operator, are also available. Process enclosures are used to reduce airborne particle release: the shredder and tile scrap crushers are equipped with partial enclosures, the glaze applicator and brush machines on the glaze line are equipped with enclosures, and vertical conveyors carrying raw materials and milled clay are equipped with enclosures. To reduce airborne dust migration, the facility has made an effort to isolate certain dust-generating operations: the raw material storage area, inside which tile scraps are crushed and clay and sand are ground, is separated from the body preparation room by a concrete wall; the body preparation room, inside which clay is milled and spray dried, is separated from the main production area by another wall with a self-closing bay door; and the entrance to the glaze batching area in the glaze preparation room is enclosed with hanging plastic strips. Housekeeping with water hoses, brooms, and a power sweeper is performed to reduce accumulated dust that can be re-suspended into workers' breathing zones by traffic through the facility. Respirators are also used by certain workers to reduce exposures to airborne contaminants.

Local Exhaust Ventilation: Worker exposure to airborne dust generated in the raw material area was reduced with LEV systems, partial enclosures for equipment, and a control room. Use of these controls was associated with an exposure level of 157 $\mu g/m^3$ for the clay handler. The three tile crushers, which were not operated during the site visit, were equipped with LEV ducts connected to an adjacent baghouse dust collector. The shredder, conveyors, and storage hoppers were equipped with LEV ducts leading to a baghouse dust collector in the body preparation room. The shredder and tile crushers were also equipped with ventilated enclosures to reduce dust release at material transfer points. The front-end loader used by the clay handler was equipped with a cab enclosure. The enclosure was not ventilated, however, and ERG observed a light layer of settled dust on the interior surfaces of the cab. An elevated control room that was located approximately 25 feet from the shredder was also available, but the clay handler's duties require that most of the shift be spent operating the loader rather than in the control room. The control room contained an air conditioner, but was not equipped to operate under positive pressure or to filter respirable particles. The control room was not tightly-sealed, and the door to the room was periodically left open during the sampling period. ERG observed a light layer of settled dust on the floor, walls, windows, and equipment inside the control room.

Dust generated in the raw materials area appeared to contribute to airborne dust levels in other parts of the facility. For example, airborne dust appeared to pass from the area near the shredder into the body preparation room and eventually into the main production area. To reduce dust migration to the rest of the facility from the tile crushing and clay milling operations, the raw material storage area was isolated from the rest of the facility by a wall. However, the wall contained several openings through which ventilation ducts and conveyors passed into the body preparation room. These openings allowed airborne dust to pass into the body preparation room. The storage area also contained two openings (one facing West and one facing South) through which front-end loaders and dump trucks transported raw materials from outside the facility. Reportedly, airborne dust can escape through the openings and reenter the facility through open doors in the main production area.

Worker exposure to airborne particles generated during ball mill charging operations in the body preparation room were reduced with LEV systems. The storage hoppers containing dry, milled clay were equipped with LEV ducts. A duct was connected to the top of each hopper and led to a baghouse dust collector in the room. The LEV system was reportedly designed to automatically exhaust air from one storage hopper at a time, as clay was transferred from that hopper into the ball mill below it. However, employees indicated that the automatic LEV system no longer functioned properly. Rather than exhausting air from the one hopper being emptied at a time, the system simultaneously exhausted air from all of the storage hoppers, with operators attempting to optimize air flow by manually adjusting blast gates. This potentially resulted in substantially reduced airflow rates at the hopper being emptied. The simultaneous addition of water (from pipes attached to the hoppers) while charging the ball mills with dry clay may have reduced dust release. These controls were associated with a result of 226 $\mu g/m^3$ for the ball mill operator. ERG did not observe visible dust released as clay was transferred into the ball mills during the site visit; however, workers reported that substantial airborne dust is generated at times, particularly when the mills are charged with crushed fired tile scrap.

The spray dryer chamber was serviced by a stack through which airborne contaminants and steam generated by the spray drying operation were vented from the facility. Dust release from vertical conveyors adjacent to the spray dryer was reduced with enclosures. An unventilated control room was also located near the spray dryer. The control room was not tightly-sealed, nor was it designed to function under positive pressure. The door provided a physical barrier to entry of airborne contaminants; however, the door was opened frequently (every few minutes) and was periodically left open during the sampling period. Thus, the air in the control room was frequently exchanged with air from the body preparation area. ERG observed a light layer of settled dust on the floor, walls, windows, and equipment inside the control room. An exposure reading of 337 $\mu g/m^3$ was associated with these controls.

To reduce dust migration to the main production area, the body preparation room was separated from the main production area by a concrete wall adjacent to the spray dryer work area. The wall contained two doors (a self-closing man door and an equipment door) that were kept closed during the sampling period except when in use. However, the wall contained several additional openings through which ventilation ducts and conveyors passed into the main production area. These openings, as well as the doors, allowed airborne dust to pass into the main production area similar to the way by which dust passed from the raw material storage area to the body preparation room.

The Martinelli press was equipped with two LEV ducts that exhausted air adjacent to the molds. ERG did not observe visible airborne dust being released from the press. While a result of 188 $\mu g/m^3$ was recorded for the Martinelli press operator, the primary source of exposure for this worker appeared to be the manual tile brushing and sweeping performed by this worker, which generated a substantial amount of airborne dust.

The facility used LEV systems in the press area to reduce worker exposures associated with tile pressing, tile brushing, clay reclamation from silos, and scrap green tile bin emptying.

Each of the four presses on Lines 3 through 6 was equipped with two pairs of LEV ducts. One pair of ducts exhausted air adjacent to the molds inside the presses, and the other pair exhausted air through hoods mounted under the conveyors that carried tiles out of the presses. These controls were identical on each press and were associated with exposure readings of 141 and 144 $\mu g/m^3$.

ERG evaluated the effectiveness of the LEV system for the presses on Lines 3 and 4 by measuring air velocity at two points along the openings where tiles exited the press. Air velocities of 97 fpm and 57 fpm were obtained for the press on Line 3, and measurements of 126 fpm and 97 fpm were obtained for the press on Line 4. A smoke tube used to determine airflow patterns at the press openings indicated that air was drawn towards the LEV exhaust openings as tiles were ejected from the presses, but air was expelled out of the presses (and into the indoor environment) as the forming equipment was forced downwards to compress the clay into the molds and when air jets cleaned the press molds between cycles.

One factor affecting LEV function at the presses was poor duct junctions. The conveyors that carried tiles out of the presses were not permanently attached to the presses. The hoods mounted to the conveyors were equipped with rigid duct junctions, approximately 4 inches long, that were designed to fit against the ducts attached to the presses. Several of the conveyor-mounted hoods and ducts were misaligned, resulting in gaps up to 1 inch wide. These gaps decreased the efficiency of the LEV systems by allowing air to enter ducts by alternate paths, creating turbulence and reducing air flow at the hoods. ERG observed 1 inch to 2 inches of settled dust inside the conveyor-mounted hood on Line 5.

Conveyor-mounted brush machines between the presses and dryers on each line were also equipped with LEV ducts. However, using the smoke tube, ERG was not able to detect any air motion into the exhaust openings for the brush machines on Lines 3 and 4.

Each storage silo that transferred clay to the presses on Lines 3, 4, 5, and 6 was equipped with a screen that removed oversized particles. The oversized particles from each silo were transferred through a pipe into an open bin located next to each of the presses. Each bin was positioned under a canopy hood fitted with hanging plastic strips that enclosed the top of the bin. The pipes that transferred clay into the bins were inserted through the strips. The strips did not form a complete barrier and ERG noted gaps up to 2 inches wide between some strips. One of the bins was also misaligned with the hood, resulting in a portion of the bin protruding from under the hood. ERG measured an average air velocity at the hood face (inside the plastic strips) of 38 fpm for the canopy hood on Line 4.

The forklift operator for the glaze line used a forklift to empty bins containing green tile scrap from the press area and glaze line into a wall-mounted hopper in the press area. The hopper was located above a conveyor that transported the tile scrap through the wall and into an adjacent room. The hopper was approximately 8 feet wide and protruded from the wall approximately 5 feet. A rectangular, slotted LEV hood was mounted on the wall approximately 2 feet above the top of the hopper. The hood was approximately 41 inches long and 18 inches wide with three 3-inch slots. The face of the hood was angled towards the hopper, approximately 45 degrees from the wall. A flange approximately 2 inches wide was attached along the top of the hood. Air velocity measurements indicated an average slot velocity of 248 fpm and an airflow rate of 800 cfm. Visible airborne dust was generated each time a forklift operator emptied a bin of tile scrap into the hopper. A substantial portion of the dust appeared to dissipate away from the hood indicating that the air flow and/or hood design was inadequate. Although this was just one of several sources of exposure for the forklift operator dumping the bins, these controls contributed to a respirable quartz result of 89 $\mu g/m^3$.

An LEV system was available to reduce worker exposure at the bag dumping station in the glaze preparation room. The station was equipped with two rectangular hoods mounted to the underside of the platform through which bags were emptied into hoppers. The hoods were positioned on opposite sides of the platform and were connected to a plenum along the third side of the station. The plenum was connected to a duct leading to a baghouse dust collector located at the opposite side of the glaze preparation room. Each hood drew air in through a row of 19 circular exhaust openings that were approximately 2 inches in diameter. An upper and lower flange were attached perpendicularly to the face of each hood, approximately 1 inch above and below the row of openings. The flanges on both hoods were bent towards each other either accidentally or in an attempt to improve function. This system was associated with an exposure level of 68 $\mu g/m^3$ for the glaze preparer who dumped bags for a substantial amount of the shift.

ERG obtained an average air velocity reading of 506 fpm at the openings and estimates that the hoods were capable of producing an airflow rate of 420 cfm. However, 1 inch to 2 inches of settled dust was observed along the bottom flange of each hood indicating the air velocity through the flanges was inadequate to carry dust. The dust partially obstructed several of the exhaust openings, reducing the volume of air exhausted by the hoods.

When the glaze preparer emptied bags, most of the visible airborne dust generated under the bag dumping station platform appeared to be drawn into the hoods, but visible dust occasionally escaped through gaps between the hoods and the hoppers. The majority of the visible airborne dust released above the platform did not appear to be drawn into the hoods. Hoods on both sides of the platform were equipped with detachable side plates allowing access to the hood interiors for maintenance. Up to 4 inches of accumulated dust was observed inside one of the hoods. Reportedly, accumulated dust is scraped from the interiors of the hoods once per month with a metal rod equipped with a hook, indicating that this is an ongoing problem. The power sweeper is also reportedly used to clean the floor adjacent to the bag dumping station once per shift. To reduce airborne dust migration, an open passageway between the bag dumping area and the main production area was enclosed with hanging plastic strips.

Worker exposure to airborne particles generated by liquid glaze application and tile brushing was reduced by using automated machinery equipped with enclosures and LEV. These controls appeared to effectively contain excess glaze and dust. The brush machine was also equipped with an enclosure that appeared to effectively contain visible airborne particles. The two sprayer machines were each equipped with a pair of LEV ducts. The brush machine, which swept the surfaces of the tiles, was equipped with four LEV ducts. The disk applicator machine, which produces a coarse "splatter" coating rather than a fine spray, was not ventilated.

The LEV ducts from each spray and brush machine led to an adjacent hydrofilter, a type of wet dust collector consisting of water-filled compartments through which metal baffles directed exhausted air and where particles are captured in the water. Reportedly, the contaminated water is drained and the wet collectors are refilled once per shift. All of the hydrofilters were served by a single exhaust fan, rated for 40 to 50 horsepower (HP) and capable of generating 15,000 to 18,000 cfm. Although a detailed evaluation of the ventilation system was beyond the scope of the site visit, ERG noted that it was not operating optimally. Air was being exhausted from an inactive glaze spraying machine through a hydrofilter that was not filled with water and open. Open and without water, resistance to air flow is decreased and a higher exhaust flow rate can be generated through the filter. Since all of the hydrofilters on the glaze line were powered by the same fan, the empty hydrofilter may have reduced the flow rates for the hydrofilters servicing the operational glaze sprayer machines and the brush machine. A company officer reported that empty hydrofilters can also unbalance the LEV system for the glaze line, resulting in increased air velocities through certain ducts. The increased air velocity in the ducts can cause silica to abrade the walls of the ducts, particularly in the elbows. Although use of these controls are associated with an exposure level of 150 $\mu g/m^3$, the primary source of exposure was likely the adjacent press operations, which were not influenced by the glaze line controls.

Housekeeping: Housekeeping was performed at various workstations by dry sweeping or washing with water hoses. The presence of less settled dust (after cleaning) may have reduced the potential for resuspension; however, removal of dust by dry sweeping with brooms or the power sweeper also caused dust to be resuspended. A Tennant 6550 rider power sweeper was used to clean the floor in the main production area twice during the sampling period. The power sweeper removed settled dust from the floor by dry sweeping with circular bristle brushes and vacuuming the loosened material. ERG observed dust resuspension by the power sweeper when it was used to clean the floor along a wall in the press area. The floor was covered with clay powder, and visible airborne dust was released as a brush mounted to the bottom of the power sweeper rotated along the floor. ERG also observed dust resuspension when workers dry swept work surfaces or floors with hand or push brooms. These housekeeping practices were associated with results of 82 and 89 $\mu g/m^3$, although airborne dust from the press area also contributed to the exposure level of both these workers (utility worker and glaze line forklift operator).

ERG observed workers in the body preparation and glaze areas washing floor surfaces with water hoses. As a result, the floors adjacent to the vibrating screens in the body preparation room and at the glaze line were wet throughout the sampling period, possibly reducing potential exposures from that source.

The facility is also equipped with two HyVac Model 450 industrial vacuum units rated for 1,039 cfm with no load and 873 cfm at 18-inches mercury. The vacuums can extend to all areas inside the facility and exhaust dust into a hopper leading to a blunger tank in which the dust can be recycled. One vacuum is on a pallet and can be moved where needed with a forklift. The other vacuum is stationary and hard ducted to various work points so employees can connect vacuum attachments to ducts near the point of use. Neither vacuum was used during the site visit. ERG noted that to use the more portable vacuum, a worker must handle a long length of heavy-duty corrugate plastic duct. The unwieldy nature of the duct and the fact that extending it blocks forklift traffic may account for the limited use of this system. Vacuum fittings for the permanent duct system were not evident during the site visit.

Respirators were used at the facility to reduce worker exposure to airborne contaminants. Workers are required to wear air-purifying respirators for raw material processing and glaze preparation operations. The clay handler wore a Gerson disposable half-mask N95 filtering facepiece respirator in the morning and a half-mask respirator equipped with two P100 particulate filter cartridges in the afternoon. The glaze preparer wore a half-mask respirator equipped with two P100 particulate filters while emptying bags of glaze components into hoppers. Respirator use is voluntary for other operations performed at the facility. During the sampling period, ERG observed two press operators wearing Gerson disposable half-mask N95 filtering facepiece respirators fitted with exhalation valves. The facility has a respiratory protection program and workers reportedly receive training. A wall-mounted respirator storage case in the first aid room contained a couple of half face respirators fitted with P-100 filters. The respirators were in good condition but dusty.

V. DISCUSSION

The respirable quartz exposure levels of 17 employees evaluated at Ceramic Tile Manufacturer A ranged from undetectable (three workers, primarily operating in the kiln and selection areas) to 337 $\mu g/m^3$ (spray dryer operator). Ten of the results indicate exposure levels exceeding OSHA's 8-hour TWA permissible exposure limit (PEL) for quartz (measured as respirable dust containing quartz). The conditions and activities associated with these sample results represent a typical work shift at Ceramic Tile Manufacturing Facility A.

A gradient in exposure readings for certain workers in the main production room suggests that exposure levels for some workers were affected more by ambient respirable silica than their work activities. In the main production room, the highest exposure levels were reported in the press area, where visible dust was generated by equipment (presses) and employees activities (dry sweeping). The lowest exposures were associated with workers at the opposite end of the production line, where little airborne dust was observed and workers primarily handled fired tiles in kiln and quality control or packaging activities.

This facility uses a number of controls to reduce employee exposure to dust; however, the equipment was not uniformly effective. Operations such as raw materials handling, spray drying, pressing, and bag dumping were noted as sources of visible dust despite local exhaust ventilation. Low air flow (inadequate to capture dust) or disconnected ducts were noted for some of these ventilation systems.

Housekeeping activities may both reduce and contribute to employee exposure to respirable silica. Some areas were wet-mopped frequently, while others were dry bushed with brooms (also frequently) or a riding sweeper (twice per day). Visible dust was generated by manual and mechanical sweeping.

VI. REFERENCES

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Appendix A

Detailed Discussion of Exposure Results, Potential Sources of Silica Exposure, and Workpractices

This Appendix presents detailed observations on workpractices at Ceramic Tile Manufacturer A, as noted by the ERG team and summarized in the site visit report. Table A1 summarizes the amount of time employees spent performing various activities.

Clay Handler

The clay and sand raw materials were received and stored in open piles inside a covered storage area located at the South end of the facility. Front-end loaders and dump trucks transported materials into the area from outside the facility through two openings. The area contained the clay shredder, conveyors, storage hoppers for milled raw materials, and an elevated control room. The area also contained an open pile of fired tile scrap and three tile crushers. The tile crushers, which had been out of service for several weeks, were not operated during the site visit. The clay handler spent approximately 80 percent of the sampling period overseeing the delivery of clay and sand from dump trucks and using a front-end loader to transfer raw clay materials into a hopper leading to the shredder. For approximately 5 percent of the sampling period, the clay handler operated the shredder from the control room. The clay handler worked in other areas of the facility performing tasks such as material weighing for approximately 5 percent of the sampling period. (Note: All workers were on lunch and rest breaks 10% of sampled time.) Settled dust accumulations of up to 4 inches were observed on the floor, walls, and equipment inside the storage room. Settled dust was also observed inside the cab of the front-end loader and the control room. Visible airborne dust was generated when dump trucks unloaded raw materials into piles inside the room and when the clay handler loaded the hoppers with clay and sand. Visible airborne dust was also released when clay was milled in the shredder and when milled raw materials were conveyed to storage hoppers. At times, the quantity of dust in the air was sufficient to substantially reduce visibility across the storage area.

Table A1. Percentage of Time Employees Spent Performing Various Activities Ceramic Tile Manufacturing Facility A January 9, 2001	
Job Title	**Activities (and associated percentage of working time)** Note: Workers on lunch/rest breaks 10% of time
Clay Handler	Overseeing dumping of clays and sand into storage piles and transferring clays and sand into hoppers with a front-end loader (80%), operating clay shredder from control room (5%), activities in other areas of facility (5%).
Ball Mill Operator	Manually attaching chutes to ball mills and charging them with dry clays and sand 85%, washing floors with hose (5%).
Spray Dryer Operator	Monitoring operations from inside the control room (10%), collecting samples of dried clay and transporting them to other areas of the facility (10%), monitoring spray drying operations from outside the control room (70%).
Press Operator (Martinelli Press)	Manually handling dry pressed tiles (35%), manually brushing tiles/sweeping (45%), forming tiles with press (10%).
Press Operator (Lines 3 & 4 and Lines 5 & 6)	Monitoring presses (75%), inspecting tiles exiting driers (10%), dry sweeping (5%).
Glaze Preparer	Transporting bags of ingredients with forklift (20%), manually opening and emptying bags of silica-containing materials into open bins (45%), dry sweeping (5%), loading ball mills with dry glaze materials from hoppers (12%), transporting and emptying bin containing emptied bags (8%).
Glazer	Disassembling and washing equipment (35%), maintaining and filling vats (35%), monitoring glaze lines and inspecting tiles (10%), washing floor with water (10%).
Silk Screen Operator	Monitoring silk screening machines (30%), filling buckets of glaze paste from source (20%), refilling silk screening machines with paste (20%), preparing cellulose fixative (20%).
Kiln Operator	Monitoring kilns (45%), using hand cart to transport tile racks (45%).
Selector (Trim Line)	Performing Q/C visual inspection of fired tiles and stacking tiles for packaging (90%).
Selector (Selection Area)	Inspection of fired tiles and monitoring conveyer belt function(90%)
Forklift Operator (Glaze Line)	Transporting and emptying bins of green tile scrap or glaze tanks with a forklift (80%), operating a power sweeper (10%).
Forklift Operator (Selection Area)	Transporting tile scrap and packaged tiles (90%).
Press Mechanic	Manually inspecting pressing and drying equipment in the production area (15%), activities in maintenance/tool room (75%).
Laboratory Technician	Sampling and inspecting materials in the production areas (75%), inspecting tiles inside laboratory (15%).

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Table A1. Percentage of Time Employees Spent Performing Various Activities Ceramic Tile Manufacturing Facility A January 9, 2001	
Job Title	**Activities (and associated percentage of working time)** Note: Workers on lunch/rest breaks 10% of time
Utility Worker	Operating a power sweeper (12%), monitoring mopping and dry sweeping floors (78%).

Ball Mill Operator

The ball mill operator spent approximately 85 percent of the sampling period preparing ball mills for charging, charging ball mills with clay and water, transferring clay slip from the ball mills into underground storage tanks, monitoring screens, and using a water hose to clean the work area. The operator prepared each mill for charging by detaching a pipe that pumped slip into underground storage tanks and aligning the loading hatch on the mill with an overhead storage silo containing milled clay and sand. To charge a ball mill, the operator used a handheld pneumatic wrench to remove bolts holding the hatch in place and manually opened the hatch. The operator then manually attached a chute sleeve to the storage silo above the ball mill and inserted the sleeve into the open hatch. The operator activated a control allowing clay, sand, and water to pour into the ball mill in the correct proportions. When the mill was fully charged with raw materials, the operator removed the chute sleeve and manually closed the hatch. The operator used a handheld wire brush to remove dried clay residue from the hatch, and then secured the hatch in place by using the pneumatic wrench to fasten the hatch bolts. While the operator charged one of the mills during the site visit, ERG observed a small amount of raw materials missing the hatch and depositing on the mill exterior. Reportedly, a large amount of materials can spill onto the mills and deck outside the hatches if the process is not monitored carefully. To fill underground storage tanks, the ball mill operator manually attached a pipe to a ball mill and operated a pump that transferred slip to the tanks through the pipe. The operator washed the floor adjacent to the screens with a water hose. For approximately 5 percent of the sampling period, the operator stood in the control room for the spray dryer.

Less than one-fourth inch to 3 inches of settled dust was observed on the ball mills, storage silos, chute sleeves, and floor surfaces. The floor adjacent to the screens was wet throughout the sampling period. Visible airborne dust was generated when the operator removed dried clay residue from ball mill hatches with a handheld wire brush and when the operator used a handheld pneumatic wrench to loosen bolts securing hatches to the ball mills. The pneumatic wrench released a stream of air that re-suspended settled dust into the operator's breathing zone. Even though the chute sleeves did not fit tightly inside the ball mill hatches, visible airborne dust was not generated by ball mill charging operations. However, employees reported that substantial airborne dust is generated when ball mills are charged with fired tile scrap. This process was not performed during the site visit.

Spray Dryer

The spray dryer operator spent approximately 10 percent of the sampling period inside a control room monitoring instrument panels for the spray dryer. The operator spent another 10 percent of the sampling period collecting samples of spray-dried clay and transporting them to other locations in the facility for testing. For this operation (performed once per hour), the operator collected samples by manually placing a scoop under the stream of spray-dried clay pouring out of the spray dryer and onto a screen. The operator used the scoop to transfer clay into an aluminum tray, and carried the tray to the control room for weighing and analysis or to a kiln in the glaze testing area, adjacent to the main production area, for weighing and analysis. For approximately 70 percent of the sampling period, the operator monitored the spray dryer, screen, and conveyors. Accumulations of less than one-fourth inch to 4 inches of settled dust were observed on the spray dryer, the conveyor under the spray dryer, and the floor under the spray dryer. Visible airborne dust was released as spray-dried clay poured out of the spray dryer and onto a conveyor through a screen. At times, the quantity of dust in the air was sufficient to substantially reduce visibility across the body preparation room.

Press Operators

ERG monitored three press operators who oversaw a total of five press lines in the main production area. One press operator ran a Martinelli press, and two operators each ran two presses in the press area. Working conditions varied slightly for each operator, as described below. The press operator who operated the Martinelli press spent approximately 10 percent of the sampling period forming tiles with the press. The operator manually pushed a control button for each production cycle, which formed two tiles. After the tiles were formed, the operator manually removed the tiles from the press and placed them on an adjacent worktable. The operator threw defective tiles into a scrap bin. After a set of six to eight tiles had been pressed, the operator manually stacked them on the worktable and brushed the edges of the stacked tiles with a handheld scouring pad. The operator also dry swept the worktable with a hand broom. The operator spent approximately 45 percent of the sampling period brushing tiles and sweeping the worktable. The operator spent approximately 35 percent of the sampling period manually placing tiles onto pallets after brushing them. Periodically, the operator was joined by a coworker and the two operators alternated tasks. Settled dust was observed on the press and work table. Visible dust was generated when the press operator swept the work table, brushed the edges of tiles, and threw defective tiles into the scrap bin.

The press operator for Lines 3 and 4 in the press area spent approximately 75 percent of the sampling period monitoring two automated presses, two automated brush machines, and two automated dryers on adjacent production lines. The operator walked between the presses and watched for malfunctions in the machinery. At one point, a misaligned tile in one of the dryers set off an alarm and the operator manually removed the tile and restarted the process. The operator spent approximately 10 percent of the sampling period inspecting tiles as they exited the dryers. The operator measured the thickness of several tiles with a handheld caliper. The operator manually removed defective tiles from the conveyor and threw them into a scrap bin adjacent to the lines. The operator spent less than 5 percent of the sampling period dry sweeping settled dust and broken tiles on the floor adjacent to the presses and dryers with a broom. The operator swept the debris into a dust pan and emptied it into a bin. The presses generated visible airborne dust as automated air jets blew residual clay from the molds before each tile was pressed. Visible airborne dust was generated when the operator dry swept the floor and emptied the dust pan into the scrap bin. Visible airborne dust was also generated when the operator manually removed defective tiles from the conveyor and threw them into the scrap bin. Settled dust was observed on the machines, conveyors, LEV ducts, and floor.

The press operator for Lines 5 and 6 in the press area spent approximately 75 percent of the sampling period monitoring two automated presses, two automated brush machines, and two automated dryers on adjacent production lines. The operator walked between the presses and watched for malfunctions in the machinery. The operator spent approximately 10 percent of the sampling period dry sweeping settled dust and broken tiles on the floor adjacent to the presses and dryers with a broom. The operator swept the debris into piles and shoveled it into a scrap bin. The operator spent approximately 5 percent of the sampling period inspecting tiles for cracks by manually removing them from conveyors and applying diesel to them with a paintbrush. The press on Line 5 was turned off 265 minutes after the start of the sampling period. The press on Line 5 generated more visible airborne dust than the presses on Lines 3 and 4. The press on Line 6 did not generate visible dust. Visible airborne dust was generated when the operator dry swept and shoveled debris from the floor. Settled dust was observed on the machines, conveyors, LEV ducts, and floor.

Glaze Preparer

The glaze preparer batched glazes by combining materials in hoppers according to batch tickets specifying the weights of the particular ingredients for each batch. The glaze preparation room was located adjacent to the main production area and contained a bag dumping station, ball mills, and glaze storage tanks. The bag dumping station was a three-sided raised platform under which a hopper could be placed. Hoppers were loaded by placing bags on the platform and pouring the contents into the hopper through a hole in the center of the platform. An adjacent storage room contained bags and supersacks of glaze components.

The glaze preparer spent approximately 20 percent of the sampling period transporting bags of dry glaze components from the storage room to the glaze preparation room. The bags were stacked in pallets, and the operator used a forklift to transport pallets of bags containing the required batch ingredients. The glaze preparer spent approximately 45 percent of the sampling period emptying bags of dry glaze components into hoppers. The glaze preparer positioned the forklift adjacent to the bag dumping station and elevated the pallet to the height of the platform. The glaze preparer removed the bags from the pallet manually or with a vacuum hoist and stacked them on the platform with one side of the bags approximately three inches from the hole in the platform. Depending on the amount of material to be added to a hopper, the glaze preparer stacked three to five bags on the platform. After stacking the bags on the platform, the glaze preparer cut along the side of each bag with a knife to allow the contents to spill out of the stacked bags and through the hole in the platform. Depending on the number of bags stacked together, material poured into the hopper from 2 inches to approximately 2 feet above the platform hole. To further empty the bags, the glaze preparer manually lifted each bag and reached across the stack to shake it approximately 1 inch to 4 inches (and occasionally up to 24 inches) above the hole in the platform. Empty bags were manually compressed and placed inside a bin behind the bag dumping station.

The glaze preparer spent approximately 5 percent of the sampling period dry sweeping spilled materials on the bag dumping station and the floor. The glaze preparer used a hand broom to sweep spilled materials on the bag dumping platform into hoppers below or onto the floor and a push broom to sweep spilled materials on the floor. Reportedly, the floor adjacent to the bag dumping station is cleaned with a power sweeper each shift.

For approximately 12 percent of the sampling period, the glaze preparer used the forklift to remove charged hoppers from the bag dumping station and transport them next to glaze storage tanks approximately 15 feet away. The glaze preparer spent approximately 8 percent of the sampling period using the forklift to unload the bin containing empty bags by opening a bay door in the glaze material storage room and transporting the bin outside of the facility. The glaze preparer emptied the bin into a trash compactor and transported it back to its original location behind the bag dumping station. Reportedly, the bin is typically emptied four times per shift.

Visible airborne dust was generated when the glaze preparer cut open bags of materials and emptied them into the hopper. Visible airborne dust was also released as the operator swept the platform and placed empty bags into the bin behind the bag dumping station. In addition, certain bags had been broken open in the storage area. Broken bags and bags covered with spilled material from broken bags released visible dust while being transported by the forklift and while being lifted and placed onto the bag dumping station platform. Accumulations of less than one-fourth of an inch to 2 inches of settled dust was observed on the bag dumping station, the walls adjacent to the station, and the bin used for disposing of empty bags. Accumulations of less than one-fourth of an inch to 4 inches of settled dust were observed on the floor under and adjacent to the station.

During the sampling period, the operator prepared three batches of glaze (each of which included several silica-containing materials). Table A2 lists the silica-containing ingredients in each of the glazes and their silica content, according to the manufacturers' material safety data sheets. The table also presents the total batch weights of the glazes and the quantities of each of the silica-containing ingredients included in them.

Table A2. Contents of Silica-containing Ingredients in Glazes Batched at Ceramic Tile Manufacturing Facility A January 9, 2001

Ingredient (% silica)	Glaze (total batch weight in pounds)		
	1000 Engobe (3,509.22)	White matte glaze (4,714.1)	Transparent gloss glaze (4,715.75)

Silica sand (99 to 99.9%)	-	130.66 pounds	869.5 pounds
Ball clay (5 to 30%)	1,320 pounds	391.98 pounds	470 pounds
Feldspar (7 to 13%)	1,089 pounds	1,239.39 pounds	1,245.5 pounds
Bentonite (up to 6%)	198 pounds	-	3.29 pounds
Limestone (3%)	-	619.46 pounds	803.7 pounds

The PBZ sample result may underestimate the actual exposure typically associated with the glaze preparation operation because the glaze preparer had reportedly charged three ball mills with batches of glaze (prepared the previous day) prior to the start of the sampling period. The glaze preparer did not charge ball mills with glaze during the sampling period. The four ball mills in the glaze preparation room were located approximately 35 feet from the bag dumping station, and each had a capacity of 4,700 pounds. The glaze preparer charges each mill with one glaze batch, which is prepared from two hoppers of dry glaze components and varying amounts of water. To charge each ball mill, the glaze preparer uses an overhead crane to transport a hopper containing glaze materials to an elevated platform above the mills. After aligning a hatch at the top of the ball mill with a gate in the platform, the glaze preparer manually opens the hatch door and inserts a metal chute. The glaze preparer then aligns the bottom of the hopper with the chute and opens a hatch in the hopper to allow glaze materials to pour into the mill. Each gate in the platform is equipped with two LEV hoods that are approximately 14 inches long and 3 inches wide. Reportedly, the hoppers and chutes do not seal tightly, and this allows dust to escape through a gap that is approximately 8 inches to 10 inches wide. The operator reported that three ball mills are typically charged per shift.

Glazer

The glazer monitored the glaze spraying operation on the glaze line. Green tiles were carried on a conveyor through three automated glaze applicator machines: a disk applicator machine and two sprayer machines. The machines were mounted above the conveyor and were equipped with enclosures through which the conveyor carried tiles. The disk applicator machine used a set of disks to sling glaze onto the tiles. The sprayer machines used aspirating or airless nozzles to spray glaze onto the tiles. Fresh glaze from tanks positioned adjacent to the conveyor and recirculated glaze from the machines pass through open vats and into the machines. The glazer also monitored glazed tiles as they were conveyed through a partially enclosed machine that brushed the tiles.

The glazer spent approximately 10 percent of the sampling period monitoring the glaze applicator machines and inspecting green tiles being conveyed to the glaze line. The glazer manually removed defective tiles from the conveyor and threw them into a bin. For another 10 percent of the sampling period, the glazer used a water hose to spray the floor of the glazing line once each hour to remove spilled clay and glaze. The glazer spent approximately 35 percent of the sampling period disassembling the spraying machines and using the water hose to wash the internal and external surfaces of the machines and the conveyor. Two of the spraying machines were washed every 2 hours, and the third was washed every 30 to 40 minutes. The glazer spent another 35 percent of the sampling period washing and refilling the glaze vats by detaching the hoses carrying glaze into and out of the vats and rinsing the equipment using the water hose. After washing the vats, the glazer reattached the hoses and refilled the vats from the glaze tanks. The floor at the glaze line was wet throughout the sampling period and no accumulations of dry glaze materials or clay were observed on the conveyors, equipment, or floor.

Silk Screening Operator

The silk screen operator monitored the silk screening operation on the glaze line. Three automated silk screen machines applied glaze patterns to green tiles. Each machine was equipped with a squeegee that forced glaze paste onto the top surfaces of the tiles through a silk screen. The operator spent approximately 20 percent of the sampling period filling buckets with glaze paste at the glaze preparation area and transporting them to the glaze line with a handcart. The operator spent another 20 percent of the sampling period refilling the silk screen machines by placing buckets containing glaze paste adjacent to the conveyor and inserting hoses through which the glazes were pumped into the machines. To load one silk screen machine that was not equipped with a pump, the operator used a plastic scoop to manually transfer glaze from a bucket onto the top of the silk screen. The operator monitored the silk screen machines and inspected the tiles for approximately 30 percent of the shift. For 20 percent of the work shift, the operator prepared a cellulose fixative solution that was applied to the tiles by automated spraying machines positioned ahead of each silk screen machine. No accumulations of dry glaze materials or clay were observed, and the silk screening operation did not generate visible airborne particles.

Kiln Operator

The kiln operator monitored the automated kilns and the automated tile-rack loading and unloading equipment. The operator spent approximately 45 percent of the sampling period standing at the ends of the kilns adjacent to the selection area watching for lights and alarms indicating a malfunction in the process. The operator also used a hand cart to transport tile-racks adjacent to the kilns for approximately 45 percent of the sampling period. No serious process interruptions occurred during the sampling period, however, a minor malfunction caused the operator to briefly enter a tile dryer. The kilns generated heat, but no visible dust. ERG observed visible airborne dust, presumable generated by pressing operations, at the South end of the kiln area during the afternoon.

Selectors (Quality Control)

ERG monitored two workers performing tile selection activities. One selector worked on the trim line (located adjacent to the selection area), and one selector worked in the selection area. The selector on the trim line stood at a workstation located at the end of a conveyor carrying fired tiles out of a kiln. A series of three fans mounted above the conveyor blew air onto the tiles after they exited the kiln and before they reached the selector's workstation. The selector spent approximately 90 percent of the sampling period inspecting fired tiles, discarding defective tiles, and stacking tiles for packaging. The operator manually removed defective tiles from the conveyor and threw them into a bin located adjacent to the right side of the workstation. The selector manually removed acceptable tiles from the conveyor and stacked them on an adjacent work table. The selector pushed the stacks of tiles along the work table to another worker who pushed each stack into an open cardboard box. A pedestal fan, facing the selector and located approximately 15 feet from the left side of the workstation, was operated during the sampling period. ERG obtained an air velocity measurement of 459 fpm at a point between the fan and the selector, approximately 2 feet from the selector. ERG did not observe visible airborne dust generation at this workstation.

The selector working in the selection area sat at a workstation located adjacent to a conveyor carrying fired and glazed tiles to an automated packaging machine. The selector spent approximately 90 percent of the sampling period inspecting fired tiles and ensuring that the conveyor functioned properly. The selector sat on a chair and leaned over the tiles as they were conveyed through the workstation. The selector manually removed defective tiles from the conveyor. Periodically, the selector climbed onto a set of stairs located adjacent to the conveyor to manually reposition tiles and enable the conveyor to function properly. Reportedly, the selector typically cleans the floor at the workstation by dry sweeping with a broom. Air sampling was discontinued after 333 minutes because the selector indicated feeling discomfort with the sampling pump and requested that the sampling train be removed. The selector reported that job activities for the rest of the work shift would consist of manually stacking packages of tiles on pallets. ERG did not observe visible airborne dust generation at this workstation.

Fork Lift Operators

ERG monitored two forklift operators: one for the glaze line and one in the selection area. The forklift operator for the glaze line spent approximately 10 percent of the sampling period driving a power sweeper in the press area. Resuspension of dust was visible as the operator drove the power sweeper. The operator spent approximately 80 percent of the sampling period using a forklift to transport tanks of glazes to the glaze line and transporting bins containing green tile scrap from the glaze line and press area to a hopper mounted to a wall in the press area. The operator used the forklift to raise the bin of tile scrap above the hopper. The operator then stood next to the hopper and used a steel pole to push against the rear of the bin to tilt it, allowing the tile scrap to fall into the hopper and onto a conveyor that carried the scrap into an adjacent room for recycling. Settled dust was observed on the tile scrap bins, the wall-mounted hopper, and the floor in the press area. Visible airborne dust was generated as tile scrap was dumped into the wall-mounted hopper.

The selection area forklift operator spent approximately 90 percent of the sampling period transporting tile scrap and packaged tiles. The operator used a forklift to remove bins of fired tile scrap from the line and transport them outside the building through a bay door. The operator emptied the bins into a pile of tile scrap on the facility grounds. The operator also used the forklift to transport pallets of packaged tiles.

Press Mechanic

The press mechanic spent approximately 15% percent of the sampling period monitoring equipment in the press area for malfunctions and walking throughout the facility observing various production processes. For the majority of the sampling period (75%), the press mechanic was not located in the press area, but in the separate tool room and maintenance shop area. At the beginning of the sampling period, the press mechanic corrected a malfunction with the dryer on Line 6 by looking into the dryer and manually removing a tile from the conveyor.

Laboratory Technician

The laboratory technician spent approximately 75 percent of the sampling period at various production lines inspecting glazes, raw materials, and tiles. The technician also collected samples of glazes and tiles for testing. The technician spent approximately 15 percent of the sampling period inspecting tiles inside a laboratory room adjacent to the main production area.

Utility Worker

The utility worker spent approximately 12 percent of the sampling period operating a power sweeper in the press area. The worker spent approximately 78 percent of the sampling period monitoring and cleaning the floor in the press area and at the glaze line. When dust and broken tiles accumulated on the floor in the press area, the worker dry swept the floor with a push broom. This activity generated visible airborne dust rising to waist height. To clean debris from the floor at the glaze line, the worker used a wet mop.